INSECTS IN RELATION TO NATIONAL DEFENSE

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Circular 7

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MOSQUITOES

***

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INTRODUCTION

Mosquitoes are proven carriers of malaria, yellow fever, filariasis and dengue, and a possible source of other dreaded diseases in this country. Many species, although not proven carriers of disease, are very annoying and may interfere with effective performance of men and livestock. Their control, therefore, is important in and about localities where men are concentrated.

DIVERSIFIED HABITS OF MOSQUITOES

All species of mosquitoes must have water in which to pass their early stages. They cannot develop in any other medium. The several different species of mosquitoes

Figure 1 - Diagram of the life history of a mosquito, Aedes sp. (1) eggs; (2) newly hatched larvae; (3) mature larvae; (4) pupae; (5) newly emerged adults.

usually found in every locality, however, have different habits, including differences in the kinds and location of water in which they breed. For example, several specie

breed generally in artificial containers, others in clean, permanent ponds and reservoirs, and still others in temporary rain pools, salt marshes, irrigation water, floodwater, snow water, and even in water contained only in tree holes.

Important mosquito-breeding places, frequently overlooked, are septic tanks, fire buckets, barrels, cracks in the ground, cisterns above ground, eave troughs, lily pools, and accumulations of water from an ice box drain.

Hoof prints of animals containing water can be very important sources of malaria mosquito breeding, and their presence requires meticulous care since it is necessary that each and every hoof print be covered with the larvicide. For this reason animals should not be allowed to roam over seepage areas and ditches where this type of mosquito breeding may result.

Although it is obvious that control measures must vary greatly, in general all species may be controlled by the elimination of the water in which they breed. Finding the particular kind and location of breeding areas is, therefore, the first step in the attack upon any and all kinds of mosquitoes.

A species survey is necessary to determine the problem and relative importance of the different kinds of mosquitoes present. The identification of the species prevalent in an area makes it possible to secure available information on the habits and greatly facilitates the location of breeding places.

COLLECTION AND DETERMINATION OF MOSQUITO SPECIES

In making a survey, both adults and larvae, or "wrigglers", should be collected and identified. Mosquito abundance varies greatly with the seasons; therefore, several months should be regarded as necessary for a fairly thorough survey. Control operations can be begun before such a survey is completed, but to undertake control work without proper information upon which to base the necessary control measures usually results in wasted effort.

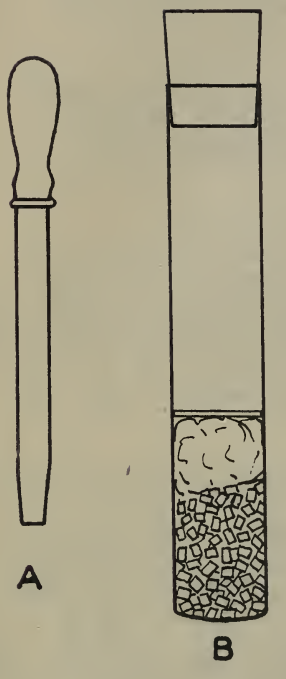

Figure 2 - a. Large-mouthed dropper for collecting larvae and pupae. b. Chloroform killing tube for collecting adults.

Collecting adult mosquitoes for identification purposes is simplest while they are biting. Such collections are usually made with a chloroform tube by inverting the tube over the insect. A killing tube, Fig. 2 b, of this type may be prepared by placing a half-inch layer of cut rubber bands in the bottom of a large shell vial or test tube, saturating the rubber with chloroform and covering with a plug of cotton. The cotton is then covered with a disc of cardboard or blotting paper. If the tubes are kept tightly corked the rubber retains the chloroform for some time. As moisture is likely to condense on the inside of the tubes, the dead mosquitoes should be removed shortly after they are killed. A pill box, with a thin layer of tissue paper or cellucotton above and below the specimens, is convenient for holding or shipping adult mosquitoes. Localities, dates, and other pertinent information should be written on the top of the box.

An electric light trap, Fig. 3, developed by the New Jersey Experiment Station especially for catching mosquitoes, has been found useful in collecting the different kinds of mosquitoes present in a given locality and determining relative abundance. Specifications for constructing this trap are available in the Bureau of Entomology and Plant Quarantine.

Samples of the wrigglers may be taken from breeding places in a dipper and then transferred by means of an

eye-dropper, Fig. 2 a, to vials containing a preservative, preferable 70 percent alcohol. It is also well to put some of the large wrigglers and tumblers (pupae, Fig. 1, (4)) in a gauze-covered jar containing some of the water in which they were found. When the mosquitoes emerge they should be killed in a chloroform tube, carefully packed in a pill box and appropriately labeled. Specimens of larvae and adults will be identified and information concerning their breeding habits given if forwarded to the Bureau of Entomology and Plant Quarantine, Washington, D. C.

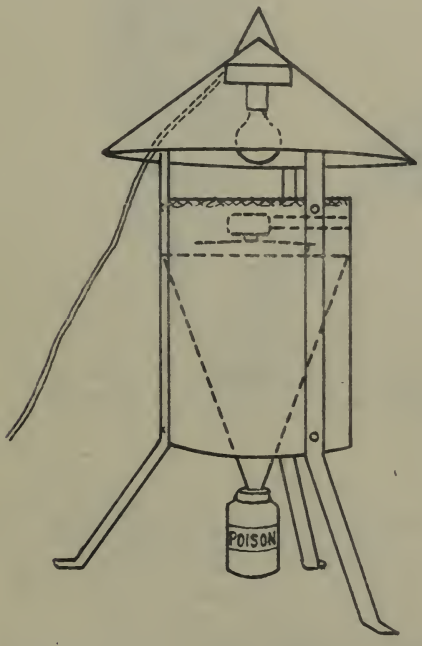

Figure 3 - Mosquito light trap. A 25-watt electric globe is mounted under the hood and a fan in the cylinder directing the air downward into a screen funnel which leads the insects into a jar containing paradichlorobenzene.

MALARIA MOSQUITOES

Malaria mosquitoes (Anopheles) can be differentiated from non-malaria species in any stage. The eggs of Anophelines, Fig. 4 c, are laid singly on the surface of water and have lateral structures that keep them afloat.

The eggs of most of the other species are glued together into a raft or boat-shaped mass, Fig. 4 a, or if the eggs are laid singly they do not have lateral floats, Fig. 4 b. The larvae of Anopheles, Fig. 5 a, are easily

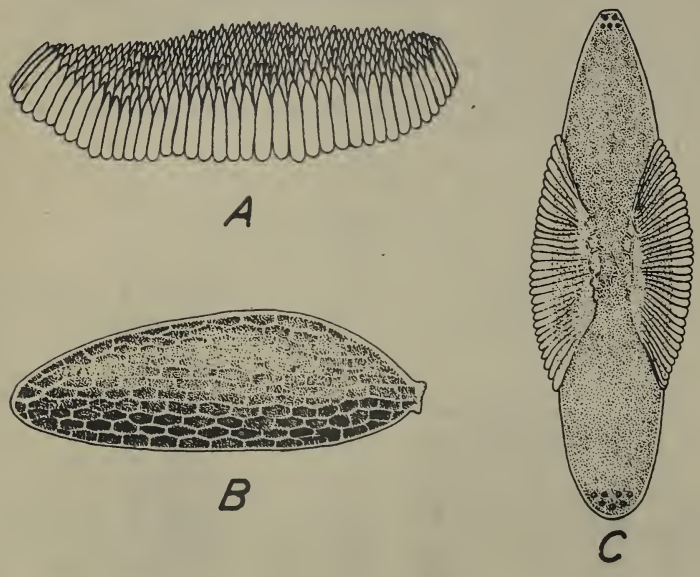

Figure 4 - a. egg raft of Culex or Theobaldia; b. egg of Aedes; c. egg of Anopheles mosquito showing lateral floats (greatly enlarged).

recognized by the absence of a breathing tube and by their usual feeding position parallel to the water surface. Other mosquito larvae have an elongated breathing tube and while at the surface hang downward with only the tip of the tube penetrating the surface film, Fig. 5 b. In the pupal stage, the breathing tubes of Anopheles are short and widely flared as compared with those of other mosquitoes.

The adult Anophelines can easily be recognized by their typical resting position, Fig. 6, a and b, the abdomen and proboscis being held in nearly a straight line and pointed at an angle toward the resting surface.

Other kinds of mosquitoes hold the body more or less parallel to the resting surface, Fig. 6 c, while the head and proboscis are bent downward at an angle to the body.

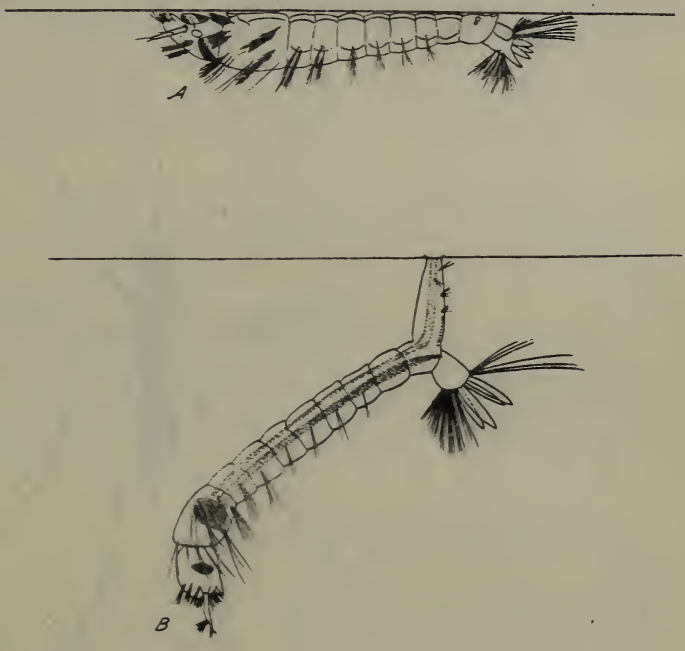

Figure 5 - Feeding positions of mosquito larvae: a. Anopheles; b. Culex.

THE YELLOW FEVER MOSQUITO

Yellow fever still exists in some of the tropical regions. In the warmer parts of the United States and in the tropics yellow fever mosquitoes are seriously annoying in buildings, and there is always a yellow fever and dengue hazard when this mosquito, Aedes aegypti L. is present. The adults are rather small and dark, with conspicuous rings of white scales on the lower joints

of the legs, and patches of white on the side of the thorax and abdomen. The lyre-shaped pattern on the back of the thorax, Fig. 7, formed by lines of white scales, is also characteristic of the species.

This species is the most thoroughly domesticated of any of the mosquitoes and apparently prefers the

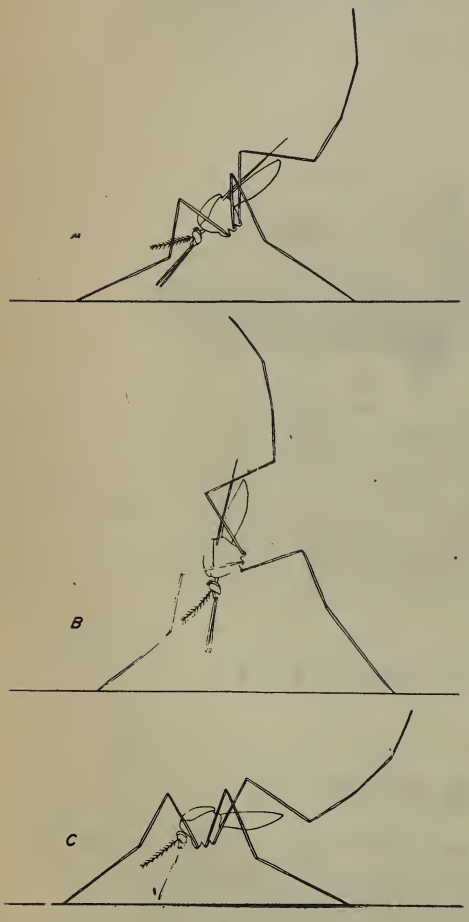

Figure 6 - Resting positions of mosquitoes: A. and B. Anopheles; C. Culex.

Figure 7 - The yellow fever mosquito Aedes aegypti. Note the lyre-shaped pattern on the thorax. Adult female. About 14 times natural size.

blood of man to that of animals. It feeds almost exclusively in artificial water containers in the vicinity of dwellings or in the dwellings themselves. Fairly clean water is preferred and may be contained in fire buckets, old cans, flower vases, obstructed eave troughs, discarded automobile casings, toilet bowls in vacant dwellings and the like. Before refilling fire barrels and fire buckets, it is best to empty them and scrub their sides thoroughly so that no mosquito eggs of this species may remain to hatch when clean water is added.

As far as is known, this species never breeds in ground pools. The adults do not fly far and when they become troublesome the breeding source can usually be found nearby.

Frequent and thorough inspection of premises by men experienced in mosquito control work is an essential part of any yellow fever control program. The surveys should be followed with prompt and effective elimination or treatment of all breeding places.

OTHER SPECIES OF MOSQUITOES

In addition to the yellow fever and malaria-carrying mosquitoes there are many species which belong to the genera Aedes, Culex, Theobaldia, Mansonia and Psorophora, which are frequently referred to as "pest mosquitoes". The breeding places, the range of distribution and the manner of overwintering of the various species differ in important aspects. The eggs of Aedes and Psorophora are laid singly on ground subject to subsequent floods, while the eggs of Culex, Theobaldia, and Mansonia are laid in rafts directly on water. Aedes and Psorophora overwinter in the adult stage, and Mansonia overwinters in the larval stage. The larvae and pupae of Mansonia have the unique habit of remaining below the surface of the water attached to the stems and roots of aquatic plants, from which they obtain air, Fig. 8. They rise to the surface only when ready to transform to the adult stage. Because of this habit, ordinary inspections do not reveal the presence or absence of these larvae, nor can they be reached by

ordinary surface larvicides, such as oil.

Of the so-called "pest mosquitoes" several species of the Aedes have been shown to be able to transmit encephalomyelitis (brain fever) of horses and man. The southern house mosquito (Culex quinquefasciatus Say) is the carrier of filariasis.

Figure 8 - A marsh is a characteristic breeding place for Mansonia mosquitoes.

PROCEDURE FOR CONTROL MEASURES

Surveys to Determine Source of Infestation

The preliminary measures to be taken in the control of mosquitoes is the making of surveys to determine where they are breeding and the kind of mosquitoes that occur in the area. An important aid in this and actual control work is the preparation of a map on which all water sources are located in relation to roads, trails and permanent landmarks in the area. Natural drainage should be indicated and proposed construction such as filling, diking or ditching shown. Determination of the direction of the prevailing air movement is important as it aids in placing the mosquito traps and determining the source of infestation. The acreage of water likely to produce mosquito breeding should be computed as such information is needed in estimating the amount of larvicide that may be required. The area must be inspected

thoroughly for mosquito larvae and adults by trained men, preferably entomologists, with a knowledge of such work. The correct interpretation of accurate data thus secured often determines the success or failure of control work. Unfamiliar species of mosquitoes, larvae and adults should be accurately identified by a specialist. As the work progresses, the range and abundance of each species should be marked on the map and correlated with data obtained from the trap records.

Control Organization

If control work is undertaken the area should be divided into districts of such size that they can be inspected thoroughly at weekly intervals by a scout inspector. These scouts should have an aptitude for the work and preferably with at least some training in biology or entomology. Each control district should be mapped in detail with all location of mosquito breeding clearly shown. The scout inspector in charge should examine the water in all kinds of receptacles, in puddles, tree holes, ditches, streams, ponds and marshes at least once a week. The results of all inspections and other facts relating to control should be reported daily to the officer in charge, who will determine what method of control is applicable and assign operations crews to carry out the necessary control work, such as treating with larvicides, draining or filling. Where larvicides are to be put out by hand equipment, it is usually advisable for from five to ten men to be detailed to a crew supervised by a foreman. Each patch of water treated with insecticides should be checked for results on the day following the treatment.

CONTROL

Mosquito breeding places are frequently man-made, Fig. 9. Among the most serious offenses are the creation of borrow pits, careless construction of sewage disposal facilities, and dumping of tin cans. Discarded tin cans should be washed clean and pounded flat since even a very small amount of water furnishes sufficient space for such species as the yellow fever carriers to breed. Borrow

pits are usually prolific breeders of malaria-carrying mosquitoes, whereas the polluted water found in sewage disposals invariably gives rise to the common house mosquito, a severely annoying pest. Road construction which intercepts natural drainage should provide suitable culverts for thorough drainage. Catch basins in storm sewers should be constructed so that pockets of water are not left standing in them.

Figure 9 - Standing water in cracks of hydraulic fills is often responsible for prolific breeding of *Aedes* mosquitoes. Such breeding conditions are difficult to handle but may be avoided or corrected by making the fills gradually or by breaking the surface with a disc harrow.

Water Management

Filling and pumping.-- The best and most satisfactory way of controlling mosquito breeding in certain kinds of low areas holding water for greater and lesser periods is by filling. Such practices are not always economical, but when put into effect control is permanent. Pumping becomes necessary under several conditions on drainage or reclamation projects, but because of the highly specialized field of hydraulic engineering frequently involved, these problems should be met by the assignment of hydraulic engineers to assist in their solution.

Drainage.-- Good drainage of camp, residential, or factory area is important from the standpoint of mosquitoes, as well as for other reasons. Mosquitoes of certain kinds may travel several miles; therefore, ditching of mosquito-breeding marshes may have to be carried out far beyond the point to be protected.

In the case of salt marshes, Fig. 10, the problem is one of preventing water from standing after high tides, and in that of fresh water marshes, of carrying off rain and spring water. Mosquitoes breeding in salt marshes lay their eggs directly on the soil where they remain until covered by a high tide or rainfall. If the water which causes the eggs to hatch is drained away by means of ditches, then the newly hatched larvae will be stranded or carried into deep water where they will be destroyed.

Fresh water marshes may cause mosquito breeding in two ways: (1) high water in spring covering land ordinarily above the summer water level will cause the mosquito eggs laid the previous summer to hatch, and (2) permanent water in the marshes furnishes a suitable medium for certain species which lay their eggs, as do the malaria-carrying species, directly on the surface of the water. These hatch within a few days and several generations may be produced each season.

The construction of drainage systems should be done preferably under the direction of a sanitary engineer who

understands the mosquito phases of the problem. Careful consideration should be given to the question as to whether or not drainage is desirable in any given marsh. Many marshes offer no problem as mosquito producers and their continuance is important in the conservation of wildlife. Where drainage is necessary, ditches can be constructed by hand digging, trenching machines, or by the use of dynamite.

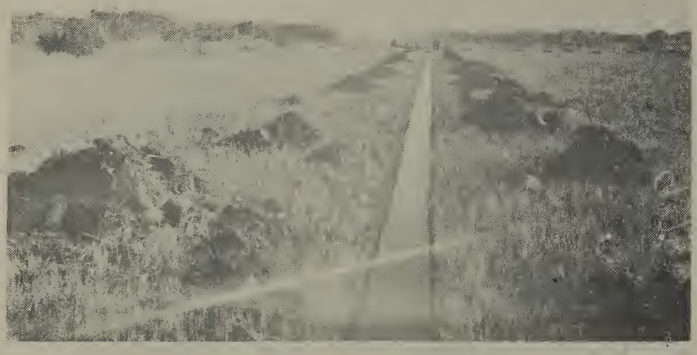

Figure 10 - A well defined ditch in tidal marshes drains pot holes and surface water. Note how piles of sods from ditch are spaced to allow drainage between them.

When drainage is not practicable or advisable it is sometimes possible to control mosquito breeding effectively by deepening lake and pond margins. Mosquito larvae cannot exist in relatively deep water subject to wave action. Absence of protective vegetation is also favorable to control by minnows and other predators. Deep margins about lakes discourage the growth of certain aquatic plants, the removal of which is the only practical remedy known for controlling the Mansonia mosquito.

Areas subject to flooding.-- Some of the most prolific mosquito-breeding areas are to be found where seasonal or periodic flooding occurs. The margins of land bordering lakes which are covered in the early spring by melting snow and heavy rains are frequently

heavy producers of mosquitoes. Meadows and swales bordering rivers which are inundated by spring freshets furnish other species an excellent breeding place. The large salt marshes, which are covered by monthly high tides, offer a particularly good haven for the vicious salt-marsh mosquitoes. If the water of such ponds, rivers or marshes can be maintained at a fairly constant level, or else can be completely excluded from the marginal zone by dams, ditches, Fig. 11, dikes and tide gates, Fig. 12, the problem will be largely solved as far as the flood-water mosquitoes are concerned.

Figure 11 - For tidal drainage the spearhead prevents wave action from clogging the outlet.

Anopheles control by impounding water and by raising and lowering water levels.-- Complete drainage of surface water is the logical method of Anopheles control where that method applies, but in the absence of a drainage outlet, it is sometimes desirable to impound water. Reservoirs and bayous, for example, favor mosquito production under natural conditions, but under impounded conditions do not. Mosquito control is brought about by the preliminary clearing along the banks and by provision for a permanent water level sufficiently high to suppress the growth of aquatic vegetation. Following

Figure 12 - Tide and spill gate.

these operations, the maintenance of a clean margin is all important. In some instances the alternate raising and lowering of such water levels is a satisfactory control measure against the Anopheles species. When the water level is lowered a few inches or a few feet the Anopheles larvae are drawn down and out of the vegetation to a new margin which furnishes no protection. As the new margin becomes overgrown with vegetation the pond is then further lowered or elevated to the original level.

Stream control.-- In slowly moving streams of uneven flow, some breeding areas can be eliminated by giving the stream bed a uniform slope. An even flow of water will eliminate quiet pools along the meandering water course. The banks of streams and ditches should be straightened out and cleared of vegetation so that sheltered pools do not exist, for it is in these that malaria mosquitoes are frequently found. Sewage-contaminated, sluggish streams or ponds often produce swarms of pest mosquitoes (Culex). Pollution should be avoided and the rate of stream flow increased by cleaning the channel.

Under certain conditions fish have proven satisfactory aids in the control of mosquito wrigglers. Usually, however, they should be considered as a supplementary control measure. Even in permanent ponds where they can readily exist and multiply from year to year, they cannot catch all the wrigglers if the margins of the ponds are thickly overgrown with aquatic plants. Under such conditions the plants must be removed so that the fish can readily move over the entire surface of the water. The most useful species are the common top minnows, Gambusia, and the killifishes, or Fundulus.

Larvicides

Various kinds of larvicides are employed where water management methods of control are not feasible, but it should be understood that they are only auxiliary and temporary methods at best. Permanent methods, such as filling, draining and elimination of flood waters are far more satisfactory and frequently more economical in the long run.

Borax.-- Water contained in fire buckets and water barrels can be treated with borax at the rate of 2 ounces per gallon of water. Water so treated cannot be used for drinking or for watering plants, but is satisfactory for dishwashing and laundering.

Oil.-- Petroleum oils have been used extensively against mosquitoes. They act as contact poisons and kill the wrigglers and tumblers by entering the breathing tubes. Light fuel oil (usually designated as #2 fuel oil) is recommended since it is easily handled in large or small spraying equipment and is economical in cost. Waste crankcase oil is entirely unsatisfactory, principally because it clogs the spray equipment, does

Figure 13 - Control of mosquito larvae by means of hand equipment.

not give a uniform film, stains the vegetation, and is injurious to wildlife. Approximately 20 gallons of oil, costing 5 cents per gallon should be sprayed over each infested acre of water surface, Fig. 13. Depending on the difficulty of covering the area, a laborer using a knapsack sprayer can treat 1 to 4 acres in 8 hours. In areas of considerable acreage, the use of power equipment is recommended. In heavy breeding waters it is usually necessary to apply the oil at 10-day intervals. Drip cans installed at the head of slow-moving streams or ditches emptying into low places are sometimes satisfactory controls until more permanent measures can be employed.

Pyrethrum oil emulsion.-- Soap emulsions of pyrethrum extract in kerosene oil are useful larvicides and are less harmful to vegetation, fish and wildlife than oil films. For use in fresh water, the emulsion can be prepared in the proportion of 8 ounces of liquid (40 percent) soap to 1 gallon of water and 2 gallons of kerosene-pyrethrum extract. For salt water one of the commercial emulsifiers may be used -- Gardinol WA concentrated, Dupenol WA, Oris WA, Aresket, etc., -- at the rate of 2 ounces to 1 gallon of water and 2 gallons of the pyrethrum extract. The latter should contain the equivalent of 1 pound of pyrethrum flowers per gallon of oil. In order to reduce the cost, No. 2 fuel oil is sometimes used in place of kerosene. To prepare the larvicide, the oil-pyrethrum extract is added slowly, with thorough mixing, to the water and soap mixture until a smooth emulsion is formed. This stock solution is to be diluted with water at the rate of 1 part of emulsion to 10 parts of water and sprayed on the breeding places at the rate of about 50 gallons per acre.

The cost of materials and application of pyrethrum oil emulsion compares favorably with that of oil.

Paris green.-- Paris green is highly toxic as a stomach poison to mosquito larvae and is used extensively in the control of malaria-carrying species. It is effective in very small quantities, from 1/2 to 1 pound per acre. Since these larvae feed at the surface of the water, the material can be applied economically as a dust mixed with an inert diluent. Powdered soapstone, talc,

diatomaceous earth or lime may be used at the rate of 4 or 5 parts to 1 of Paris green. Airplanes have been employed under certain conditions for dusting large areas of marsh breeding grounds, Fig. 14. Caution: Paris green is a violent poison and should not be issued for use except on written order from the Sanitary Officer. It should not be stored with or near food supplies. It should be used only under supervision, of an authorized officer and since it may adversely affect fish, should be used only as a last resort, and never in excessive quantities.

Figure 14 - Paris green dusting by airplane for control of Anopheles mosquitoes.

Clearing of Aquatic Vegetation

The cutting of dense grass, cattails and other rank growths found in swamps and marshes is sometimes necessary in order to obtain effective coverage with larvicides. The cut vegetation should be removed from the water surface.

PROTECTION FROM ADULT MOSQUITOES

Screens, bed nets, repellents, contact sprays and fumigants are all employed for protection against mosquito annoyance.

Screens

In the screening of windows galvanized or copper screens are usually employed; in the tropics and in coastal areas non-corrosive metals, such as cold-drawn copper or monel metal, are advised. Screen with at least 16 meshes to an inch should be used. Eighteen-mesh screen is preferable in the tropics, as small specimens of the yellow fever mosquito can pass through 16-mesh wire. When non-corrosive screening is not available black enamel applied lightly to each side of the screen will greatly prolong its life. This is also a method of reducing the size of the openings in coarse screen wire. To be effective, the window screens must be full length and all frames well fitted, as mosquitoes will find entrance through very small openings. All screen doors should open outward and be provided with springs to assure tight closing. Chimneys should also be screened against mosquitoes.

Bed Nets

Wherever there is danger of malaria or yellow fever, or where pest mosquitoes cannot be controlled before barracks are occupied, the judicious use of bed nets is suggested. They are also effective when men are required to sleep in tents; however, in any instance the degree of protection which can be attained by the use of mosquito nets is in direct relation to their proper use. Nets should be rectangular, made of a good grade of bobbinet that will not pull out of shape, and preferably bound with muslin around the bottom. Bed nets must always be adjusted so that no part of the netting will touch

the sleeper; the lower edges of the netting must be completely tucked in under the bedding so that the mosquitoes cannot gain entrance.

It is a good idea to roll the nets up during the day so as to prevent mosquitoes from hiding within the folds. All nets should be inspected at regular intervals and holes mended, since mosquitoes will enter any available opening.

Sprays

Kerosene extract of pyrethrum is very effective as a contact spray and is useful in destroying mosquitoes that have gained entrance to screened buildings. Systematic spraying of dwellings and barracks has been shown to aid in reducing malaria infections in some instances.

Out-of-door gatherings can be protected against flights of the adults for 2 or 3 hours by spraying pyrethrum emulsion (formula given under pyrethrum oil emulsion, page 19, except that kerosene should be used instead of fuel oil because of the danger of the fuel oil staining clothing when used) throughout the vegetation, grass, and buildings a short time before the meeting convenes. Spraying of this sort is best accomplished by the use of power equipment to produce a fog mist. Care should be taken not to let the spray fall on automobiles, as it will spot highly polished surfaces. For protection of an area 75 feet square, about 33 gallons of spray is required. This spray is not disagreeable to those attending the gathering and if properly mixed does not burn foliage or stain clothing.

Repellents

The pyrethrum spray is also effective temporarily as a mosquito repellent when sprayed on the ankles or the clothing. For application on the skin a mixture of a concentrated extract with a non-irritating oil such as petrolatum or liquid vaseline may be used. Oil of citronella and other essential oils have been used as temporary repellents. One formula which has been recommended consists of 1 part of oil of cedar, 2 parts of citronella and 2 parts of spirits of camphor. Certain proprietary products have also been used with success for periods of an hour or so. One of the best of these is composed of diethylene glycol monobutyl ether acetate and diethylene glycol monoethyl ether, and is sold under the name of

"Sta-Way". It is manufactured by the National Carbon Company, Cleveland, Ohio.

MUNICIPAL AND COUNTY MOSQUITO ABATEMENT DISTRICTS AND OTHER LOCAL MOSQUITO CONTROL AGENCIES

Defense operations may be located within or adjacent to a local mosquito control agency which is active in fighting mosquitoes. In this event, the military unit can obtain its greatest benefits by entering a cooperative agreement with the local agency. The latter is well informed on the peculiar condition obtaining in the area and consequently can give valuable aid in making a speedy survey and outlining a control plan. Moreover, both agencies should welcome the opportunity to extend the area protected from mosquitoes, since mosquitoes produced many miles beyond the boundaries of a military reservation may migrate in swarms to harass the encampment. This is especially true where cantonments are located near tidewater.

Mosquitoes may affect the cantonment and the adjoining local community in many ways, particularly in carrying disease and interfering with recreation. When combating malaria and yellow fever, it is sometimes necessary to extend mosquito control operations well beyond the confines of the cantonment and even to the nearby communities in order to protect the military personnel when on temporary leave. Observations have shown that the greatest number of malaria cases are contracted at dusk and at dawn. Infection is, therefore, very likely to take place at a time when the greatest number of men enjoy a few hours' leave. Even when disease is not present the morale of the personnel may be lowered by these pests which interfere with work, rest and relaxation.

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